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ULTRA-LOW FREQUENCY

OSCILLATOR

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INSTRUCTIONS

for

Model 400-A

SERIAL NO. 431

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KROHN-HITE CORPORATION

580 Massachusetts Ave., Cambridge 39, Mass., U.S.A.

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FIGURE 1 - Model 400-A ULTRA-LOW FREQUENCY OSCILLATOR

SECTION I - GENERAL DESCRIPTION

1. TECHNICAL SUMMARY

FREQUENCY RANGE: 0.009 cps to 1,100 cps, continuously variable in 5 decade bands.

BANDS	MULTIPLIER	FREQUENCY
1	1/100	0.009 - 0.11
2	1/10	0.09 - 1.1
3	1	0.9 - 11
4	10	9 - 110
5	100	90 - 1,100

FREQUENCY CONTROL: An engraved, single scale, individually hand calibrated rear illuminated dial, controlled by a 5:1 vernier drive, and calibrated logarithmically from .9 to 11 direct reading in cycles per second; dial is 5" in diameter with an effective scale length of approximately 8" per band or a total effective scale length of 40" for the range 0.009 cps to 1,100 cps.

FREQUENCY CALIBRATION ACCURACY: ±2% after initial warm-up.

FREQUENCY STABILITY: Drift, including initial warm-up, less than 1%; drift, for a ±10% change in line voltage, less than ±0.05%.

OUTPUT WAVEFORMS: Sine wave and square wave simultaneously.

SINE WAVE OUTPUT:

POWER: 25 milliwatts (maximum).

VOLTAGE: 10 volts rms open circuit; 5 volts rms across a 1,000 ohm load.

AMPLITUDE: Constant within ±1 db over the entire frequency range from 0.009 cps to 1,100 cps at constant line voltage; within ±0.25 db for a ±10% change in line voltage at any constant dial setting.

IMPEDANCE: Approximately 1,000 ohms when the output amplitude control is set for maximum output.

CONTROL: Potentiometer labelled RMS VOLTS calibrated logarithmically in rms volts, open circuit, from 0.01 to 10.

CIRCUIT: Direct coupled from the cathode follower output stage of a feedback loop.

HARMONIC DISTORTION: Less than 1% at any output level setting.

LOAD IMPEDANCE: Minimum load impedance is 1,000 ohms for less than 1% distortion when the output control is set at maximum; at lower settings somewhat lower impedance loads may be used without exceeding 1% distortion.

1. TECHNICAL SUMMARY (cont'd)

SINE WAVE OUTPUT:

HUM LEVEL: Less than 0.1% at any output level setting.

SQUARE WAVE OUTPUT:

VOLTAGE: 20 volts, peak to peak, open circuit. 10 volts, peak to peak, across 10,000 ohm load.

AMPLITUDE: Constant within ±1% over the entire frequency range from 0.009 cps to 1,100 cps at constant line voltage; within ±10% for a ±10% change in line voltage at constant frequency.

IMPEDANCE: Nominal impedance is 10,000 ohms. Lower values of load impedance will not damage the instrument.

CONTROL: The square wave output is fixed; no control for varying the amplitude is provided.

CIRCUIT: Direct coupled from a multivibrator which is triggered by the sine wave.

SQUARE WAVE SPECIFICATION: Rise time 0.5 to 1.0 microsecond on band 5; 1 to 2 microseconds on bands 1 through 4; symmetrical within 8%; flat top with no droop at any frequency because of direct coupling. Positive and negative half-cycle amplitude symmetrical about zero within ±10%.

CONTROLS: TUNING
RMS VOLTS
POWER OFF-ON Switch

TERMINALS: Three multi-purpose binding posts.

POWER REQUIREMENT: 105 to 125 volts
50 to 60 cycles (can be modified for 400 cycle operation).
45 watts

FUSE PROTECTION: 1 ampere, slow-blow.

TUBE COMPLEMENT: Furnished with instrument: 4-6SL7-GT, 3-6SN7-GTA, 1-6SR7, 1-6AX5-GT.

FORM: Sturdy aluminum cabinet, overall dimensions 12" wide, 7" high, 8" deep. Weight 19 lbs. net, 21 lbs. shipping. Available with standard rack panel. Overall dimensions 19" wide, 8-3/4" high, 7-1/2" deep. Weight 22 lbs. net, 26 lbs. shipping.

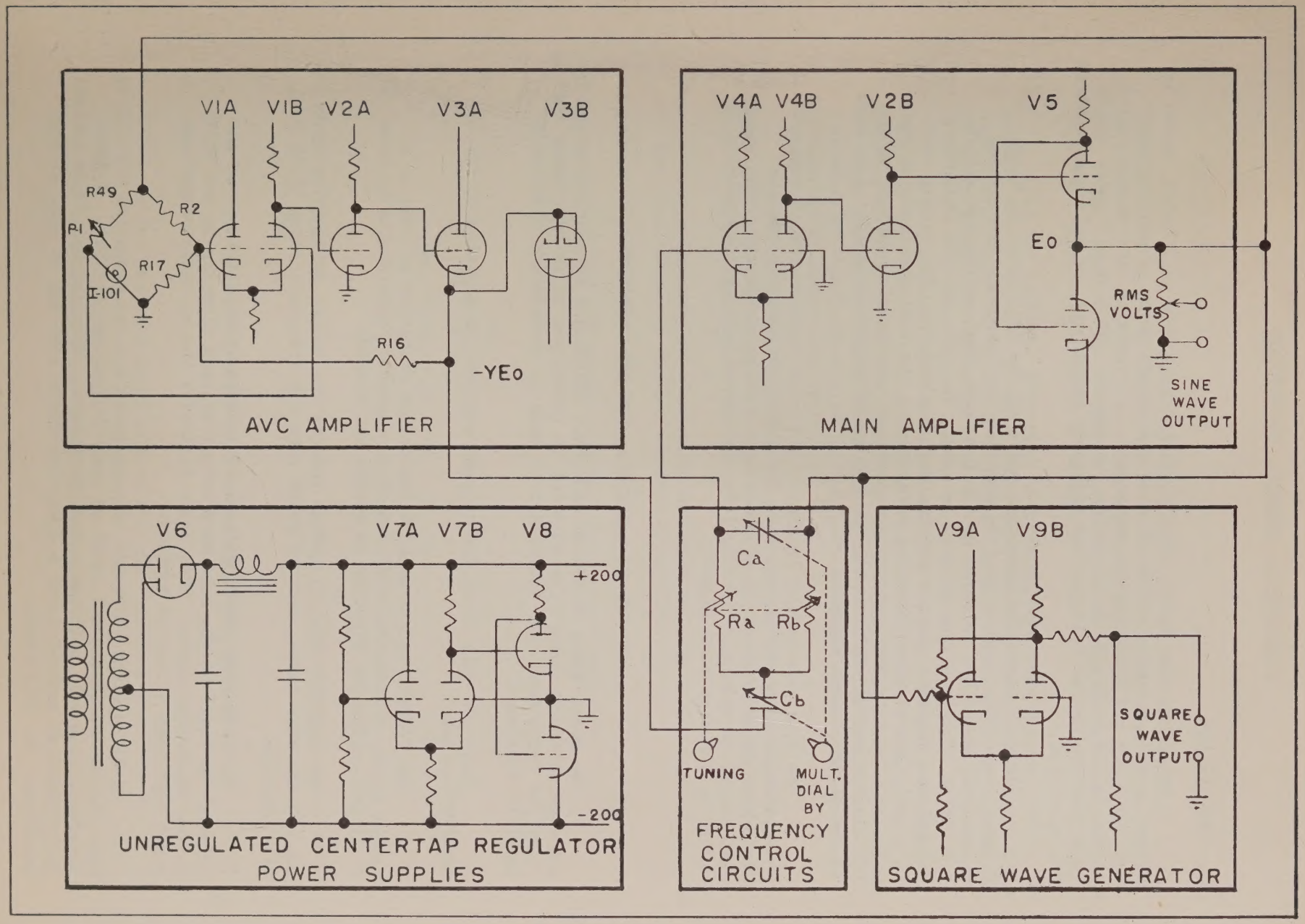


FIGURE 2—SIMPLIFIED BLOCK DIAGRAM

SECTION I - GENERAL DESCRIPTION

2. DESCRIPTION

The Krohn-Hite Model 400-A ULTRA-LOW FREQUENCY OSCILLATOR, shown in Figure 1, is a reliable source of sine and square waves at any frequency between 0.009 and 1,100 cycles per second. It operates from an a-c source of 105 to 125 volts, 50 to 60 cycles per second. An integral power supply furnishes the heater voltages and regulated center tap d-c voltages required for operation.

Figure 2 shows the essential units of the Oscillator in block diagram form. The network section contains the frequency determining parameters, which are selected by the frequency dial multiplier switch. A modified RC bridge type circuit is used. The main and AVC amplifiers provide the required signals for the bridge elements. The tuning control is a dual tapered potentiometer, which varies the time constants of the network. The sine wave output is maintained very nearly constant by the AVC element in conjunction with the AVC amplifier which applies a voltage to one of the bridge elements.

The sine wave output is controlled by a logarithmically tapered potentiometer connected directly to the output to maintain hum and distortion in constant ratio to the output sine wave voltage. The square wave output is obtained directly from the square wave generator which is driven by the sine wave signal.

SECTION II - INSTALLATION AND OPERATION

The Model 400-A ULTRA-LOW FREQUENCY OSCILLATOR is completely checked and then carefully packed for shipment to insure you of an instrument that is ready for operation. The Oscillator is easy to operate and requires no initial adjustment.

There are only three front panel controls in addition to the "ON-OFF" switch.

The TUNING control selects the output frequency as read on a single scale, illuminated dial, which is engraved logarithmically from .9 to 11 and calibrated directly in cycles per second.

The MULTIPLY DIAL BY switch selects the proper multiplying factor for all the five bands, each of which covers a frequency range of 12 to 1 with overlap.

The sine wave RMS VOLTS control is logarithmically tapered and adjusts the level of the sine wave output as read directly in rms volts on the calibrated scale. This scale indicates the unloaded output and reads high when a load is applied.

A minimum load of 1,000 ohms is specified to insure low distortion when the RMS VOLTS control is at or near the maximum setting. A lower impedance load will not damage the instrument. When the RMS VOLTS control is operated at reduced level a lower impedance load may be used without increasing the distortion.

1. THEORY OF OPERATION

There are two essential requirements that must be realized in any oscillator in order to generate low distortion oscillations with constant amplitude. The internal loop gain* must be positive or regenerative with zero phase shift at the frequency of oscillation and at this frequency the gain must be precisely equal to unity.

If the internal loop gain is greater than unity by any finite amount, the amplitude of oscillation will build up until it saturates the amplifier. When the internal loop gain is less than unity the amplitude of oscillation will diminish to zero.

If the phase shift in the amplifier at the resonant frequency deviates from zero, the frequency of oscillation will no longer be determined entirely by the RC network parameters. Since the requirements for zero phase shift must be maintained in the internal loop, the frequency of oscillation will be "pulled" to satisfy the necessary conditions of zero phase shift.

This frequency "pulling" is minimized by using high gain, wide band amplification to provide a steep rate of change of phase shift about the resonant frequency.

For the purpose of circuit analysis the simplified circuit diagram of the oscillator, as shown in Figure 3, applies.

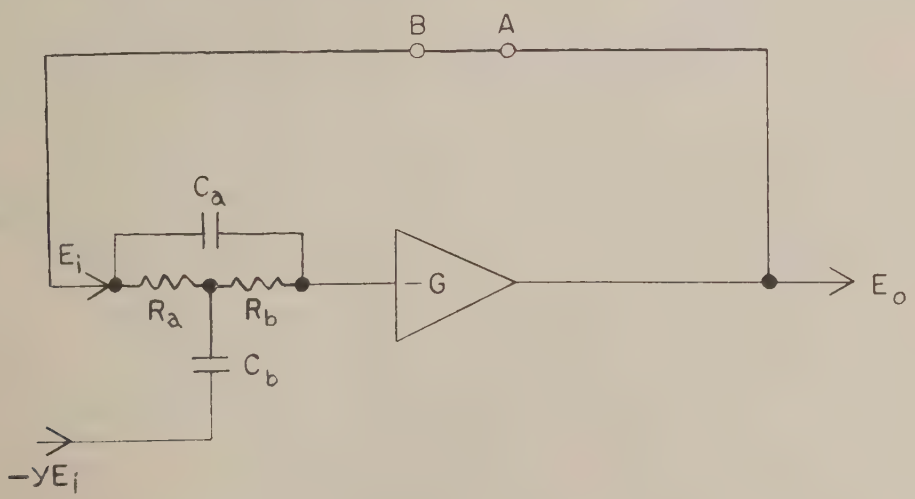


FIGURE-3 — SIMPLIFIED CIRCUIT DIAGRAM

* The internal loop gain of the oscillator as shown in the simplified circuit diagram in Figure 3, is the voltage amplitude at point A when the loop is opened between A and B, and unit voltage impressed at B.

If the internal loop is broken between A and B, and a unit voltage E_i is impressed at B, the internal loop gain is given by the following equation:

$$(1) \qquad \frac{E_o}{E_i} = -G \frac{p^2R_aR_bC_aC_b + p(R_bC_a + R_aC_a - yR_aC_b) + 1}{p^2R_aR_bC_aC_b + p(R_bC_a + R_aC_a + R_aC_b) + 1}$$

Where $-G$ represents the gain of the amplifier and $p = j\omega$.

In the Model 400-A, $R_a = R_b$ and $C_b = 10\ C_a$. Thus $R_bC_a = R_aC_a = 10\ R_aC_b$. If $R_aR_bC_aC_b = T^2$, it can be shown that $R_bC_a = R_aC_a = T/\sqrt{10}$, and $R_aC_b = T\sqrt{10}$.

By substitution into equation (1) the following equation is obtained.

$$(2) \qquad \frac{E_o}{E_i} = -G \frac{p^2T^2 + \sqrt{10}\ pT(.2 - y) + 1}{p^2T^2 + \sqrt{10}\ pT(1.2) + 1}$$

The internal loop phase and amplitude response versus frequency for this circuit is shown in Figure 4. At the high and low frequencies the gain levels off to -G. Where $(\omega T)^2 = 1$, or $(\omega = 1/T)$ the gain dips to a minimum value.

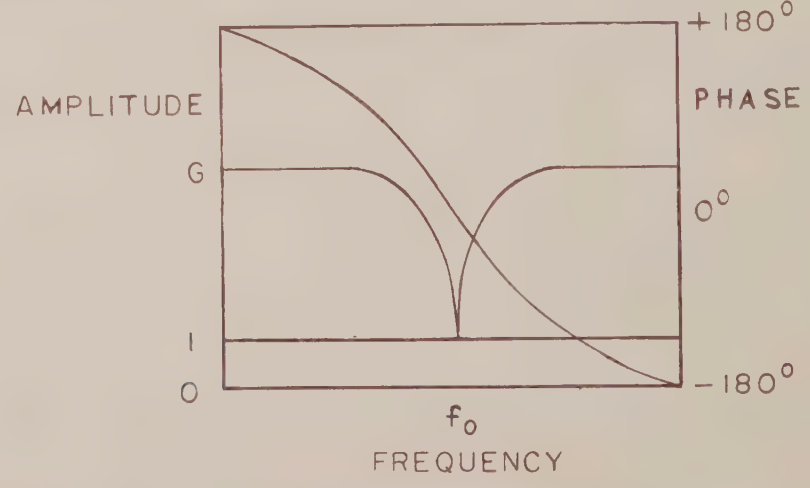


Figure 4 - OPEN LOOP PHASE AND AMPLITUDE RESPONSE

From the curve of phase angle versus frequency it can be seen that for the frequency of oscillation (f_o) the phase shift is 0° and for higher and lower frequencies the phase shift becomes 180°, thereby giving degeneration of the higher harmonics and regeneration of the fundamental.

At the frequency of oscillation (f_o where $\omega = 1/T$) equation (2) reduces to:

$$(3) \qquad \frac{E_o}{E_i} = -G \frac{.2 - y}{1.2}$$

To satisfy the essential requirements of an oscillator, equation (3) must be precisely equal to unity and E_o must be in phase with E_i. If $y = .2 + 1.2/G$ equation (3) reduces to unity. The phase relationship is satisfied by using an odd number of stages of amplification.

The AVC amplifier and the voltage sensitive device I-1 maintain equation (3) equal precisely to unity, independent of variations in the internal loop gain by maintaining $y = .2 + 1.2/G$. The voltage sensitive device is the tungsten element of a small incandescent bulb whose resistance varies with the dissipated power. Since the power across the element is obtained directly from the oscillator output, the resistance of the element varies with the amplitude of oscillation. If the element is the only voltage sensitive device in the AVC circuit, the amplitude of oscillation must adjust itself until equation (3) is precisely equal to unity.

The operation of the AVC amplifier and the voltage sensitive device may be understood more easily, for example, if we assume that the output amplitude E_o of the Oscillator decreases due to a decrease in the gain G of the main amplifier. This results in a proportional decrease in the signal at the grid of V-1A. The signal at the grid of V-1B will decrease more than the one at V-1A because the resistance of the voltage sensitive element, I-1, will decrease with decreasing voltage. The error voltage, resulting from this differential decrease in amplitude, is amplified by the AVC amplifier and increases the output of the AVC amplifier, $-yE_o$. This error voltage appearing at the output of the AVC amplifier restores the amplitude to approximately its original level.

The amplitude must decrease slightly below its original level, to provide an incremental decrease in the resistance of the tungsten element. This restores the internal loop gain to unity by increasing y to compensate for the decrease in gain, G, of the main amplifier.

2. SQUARE WAVE GENERATOR

The square wave generator consisting of both halves of tube V-9 is basically a bistable multivibrator triggered directly from the sine wave output of the Oscillator. The square wave output is obtained from the plate of V-9. Resistor R-51 is used to pull the d-c level of this output to zero.

SECTION IV - CIRCUIT DESCRIPTION

1. POWER SUPPLIES

The Model 400-A has an electronically regulated center tap power supply. The UNREGULATED SUPPLY uses a full-wave rectifier tube V-6 (6AX5) whose output is filtered by a condenser input single section pi filter consisting of C-17, C-18 and L-1, and supplies an unregulated d-c voltage of approximately 440 volts.

The CENTER-TAP REGULATOR consisting of tubes V-7 (6SL7) and V-8 (6SN7) divides the 440 volts into two balanced or equal positive and negative supplies, +220 and -220 volts with respect to ground.

The CENTER-TAP REGULATOR adds the negative and positive of the 440 volt UNREGULATED SUPPLY through two equal resistors R-39 and R-40 and compares the sum with chassis ground in the differential amplifier V-7. Since the comparison resistors are equal and the reference voltage is chassis ground, the unregulated voltage (440 volts) is divided into two balanced or equal and opposite voltages, +220 and -220 volts with respect to ground. The output of V-7 is coupled to V-8 which acts as a variable resistance to compensate for load variations in either the +220 or -220 volt busses.

2. MAIN AMPLIFIER

The main amplifier consisting of tubes V-4 (6SL7), V-2B (6SL7), and V-5 (6SN7) sustains the oscillations at the frequency determined by the RC network and provides the gain necessary for harmonic degeneration.

The output of the RC network is fed to the first stage of the main amplifier V-4. A balanced input amplifier is used in the first stage to reduce drift in the d-c output level with variations in line voltage. Another amplifier, V-2B provides the additional gain necessary to maintain the specified distortion and amplitude constancy. The second amplifier drives the output amplifier V-5 which operates as a cathode follower to deliver the rated power output.

3. AVC AMPLIFIER

The AVC amplifier consisting of tubes V-1 (6SL7), V-2B (6SL7), and V-3 (6SK7) maintains the amplitude of oscillation very nearly constant independent of frequency. The operation of the AVC amplifier can be understood more easily by referring to the simplified block diagram shown in Figure 2.

The basic amplitude discriminator is a bridge whose four resistance arms consist of R-2, R-17, P-101 in series with R-49 and I-101, which is a 3 watt 115 volt incandescent tungsten lamp operating as a voltage sensitive element. The bridge is driven from the output of the main amplifier, and the output of the bridge is amplified in the differential input amplifier V-1.

A second stage of amplification, V-2A, provides the additional gain required to maintain low distortion. The output of V-2A drives the output amplifier V-3, which functions as a cathode follower to maintain the

AVC signal at its required impedance level. The overall gain of the AVC amplifier is maintained very nearly constant by feeding back degeneratively a portion of the output signal via R-16 to the input amplifier V-1. Additional AVC action is provided by V-3 diodes when excessive signals are encountered in the AVC amplifier.

4. SQUARE WAVE GENERATOR

The square wave generator consists basically of a bistable multivibrator, triggered directly from the sine wave output of the Oscillator. This triode multivibrator is designed to trigger easily, and have a fairly fast rise time to provide a satisfactory square wave output.

SECTION V - MAINTENANCE

1. SIMPLIFIED MAINTENANCE

All the components of the Model 400-A are of the highest quality and should have a long trouble-free life since they are operated well below their manufacturer's rating. The following procedure may facilitate locating the source of trouble if the Oscillator does not function properly.

A one-ampere slow-blow cartridge fuse, located in the back of the chassis, is used in the primary circuit of the power transformer to protect the power supply components from short circuits. The rating of this fuse was selected for proper protection of the instrument and should be replaced with the same type and rating.

To take the chassis out of the cabinet, remove the two lower innermost screws on the rear plate and slide the chassis out to the front.

If a fuse failure is detected the following procedure is recommended before replacing the fuse.

(a) Check for a faulty rectifier tube, 6AX5-GT.

(b) Short circuits in the 4MFD filter condensers, C-17 and C-18 used in the unregulated portion of the power supply, can best be detected by connecting an ohmeter across the terminals directly.

(c) Check for shorts to chassis from the positive or negative voltage busses. One convenient test point for the +220 volts is the plate of the 6SL7-GT (V-7 pin 2). A convenient test point for the -220 volts is the negative side of the 4MFD filter condenser, C-17 or C-18. If a short to ground exists, check all the tie points connected to it.

(d) The d-c resistance of the power transformer primary should be 3.8 ohms. A much lower resistance probably indicates a shorted primary.

The likeliest source of failure is the vacuum tubes since they have an inherently shorter life. Check first to see if all the tubes are inserted securely in the sockets. It is possible for them to be loosened in shipment. At the same time note if each tube's filament is lighted. If the unit then fails to operate properly and the correct plate and heater supply voltages are present, check the possibility of a faulty tube. Obtain a new 6SN7-GTA*, 6SL7-GT, 6V6-GT and 6SR7, and then one at a time substitute the new tube in each position in the oscillator where it is used. The location of each vacuum tube is clearly marked on the chassis adjacent to the tube.

The AVC element, I-1, may be checked by removing it from the socket and connecting an ohmeter across its contacts. A resistance less than 200 ohms or greater than 1,000 ohms probably indicates a defective element. I-1 is a conventional 3 watt 115 volt incandescent bulb with a bayonet base. If any difficulty is experienced in obtaining a replacement, write to our Service Department, or substitute a standard screw base bulb and socket. If it is necessary to substitute a new element, the setting of P-1 may have to be changed. To check this, set the sine wave RMS VOLTS control on the panel to 10 volts and measure the voltage across the output terminals with a high impedance meter or oscilloscope. Adjust P-1 to obtain an output of 10 volts.

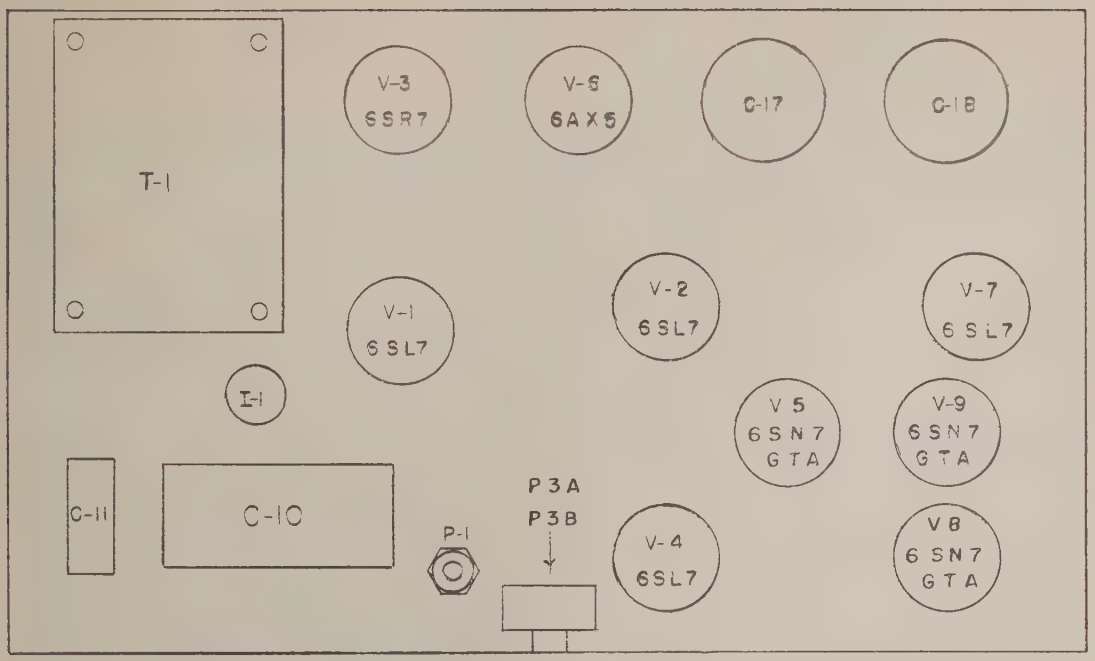
2. DETAILED MAINTENANCE

In most cases, one of these substitutions will effect a cure. If, however, this approach does not help, a more detailed test must be made. Location of components to check can be facilitated by reference to the schematic, Figure 7, and the top and bottom views, Figure 5. In addition, Figure 8 provides a vacuum tube voltage and resistance chart which gives the correct operating voltage on every pin of each tube. Any appreciable discrepancy between the existing voltage or resistance as measured and the correct one, as shown in Figure 8, should be investigated fully. The positive d-c supply voltage (pin 2 of V-7) and the negative voltage (negative side of C-18) should be of equal magnitude (less than 20 volts different). Figure 7 shows a nominal value of +200 and -200 for these voltages. Their correct value at 115 volts line is +220 and -220. With ±10% line voltage change they will vary ±10%. To localize the trouble within a circuit, refer to the detailed discussion below. If all d-c voltages and resistances are correct, but the oscillator does not function properly, a signal tracing analysis should be made as described on page 22. If erratic operation occurs only on some bands, see Frequency Control Circuits on page 21.

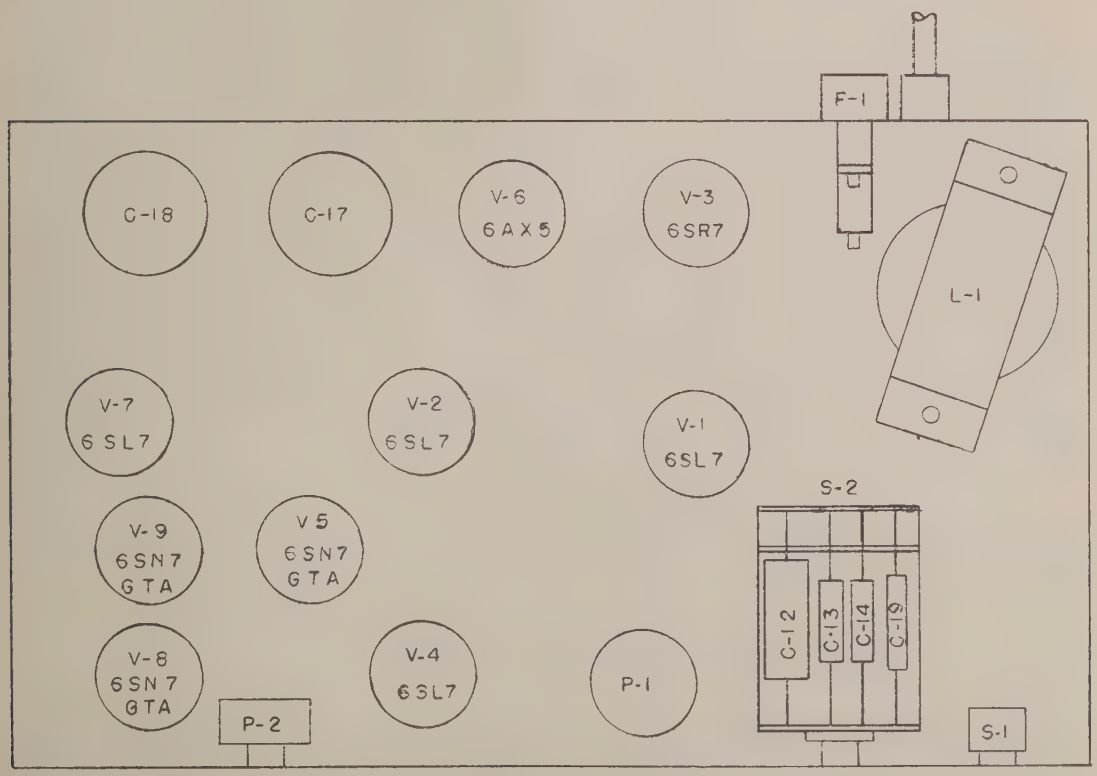
A. POWER SUPPLIES

If the Oscillator is not functioning when the rated line voltage is applied and the instrument is powered as indicated by the pilot light or visible tube filaments, it is advisable to check the power supplies.

* Do not use a 6SN7-GT in place of 6SN7-GTA since the maximum heater-cathode voltage rating of the type GT is inadequate. Type 6SN7-GTB may be used.



TOP VIEW OF CHASSIS



BOTTOM VIEW OF CHASSIS

FIGURE-5 —TOP AND BOTTOM VIEW OF CHASSIS

(1) UNREGULATED SUPPLY

The 440 volt unregulated supply voltage, as derived from the cathode of the rectifier tube V-6, is filtered in a condenser input single-section pi filter consisting of C-17, C-18 and L-1. The unregulated voltage should be checked at rated line voltage.

If the unregulated voltage deviates appreciably from its proper value, replace the rectifier, V-6. When replacing V-6 brings about no change in the voltage level, check the total current drain by measuring the voltage across L-1 which under normal conditions should measure 25±5 volts. If this voltage is appreciably higher than normal the Oscillator is drawing excessive current. The excessive current may be due to a low resistance path which can occur in the 4MFD filter condenser C-18, or in the Oscillator when the output d-c levels of the main amplifier and AVC amplifier are incorrect. See "MAIN AMPLIFIER" on page 18 and "AVC AMPLIFIER" on page 19.

When the CENTER-TAP REGULATOR is not functioning properly, it may upset the normal operation of the UNREGULATED SUPPLY.

(2) CENTER TAP REGULATOR

The CENTER-TAP REGULATOR adds the positive and negative of the REGULATED SUPPLY through equal adding resistors R-39 and R-40, and compares the sum with chassis ground in differential amplifier V-7.

It is worth emphasizing that the CENTER-TAP REGULATOR divides the UNREGULATED SUPPLY into two balanced voltages. Under normal conditions the UNREGULATED SUPPLY delivers 440 volts, which is balanced by the CENTER-TAP REGULATOR into two voltages +220 and -220 volts with respect to chassis ground. If the UNREGULATED SUPPLY puts out 300 volts instead of the normal 440 volts, the CENTER-TAP REGULATOR, if functioning properly will divide the 300 volts into two equal and opposite voltages +150 and -150 volts with respect to chassis ground. When the output of the CENTER-TAP REGULATOR is balanced, irrespective of the magnitude of the voltages, the CENTER-TAP REGULATOR is functioning properly.

If the positive and negative supplies are appreciably unbalanced, their sum as measured at the grid pin 1 of V-7A will not be zero if the additive resistors R-39 and R-40 are correct. The additive resistors should be checked first by measuring the resistance between the grid pin 1 of V-7A and the +220 and -220 volt busses. Equal resistance readings measured with the Oscillator turned off, indicates that the additive resistors are the correct value.

When the center-tap regulator is unbalanced and the magnitude of the regulated negative supply is greater than the regulated positive supply, the grid pin 1 of V-7A which is normally at zero volts will be more negative. This decreases the current in V-7A and increases the current in V-7B. The plate pin 5 of V-7B, which is normally at +150 volts, should be less positive because of the increased plate current. If the plate of V-7B is not appreciably less positive than normal when the output of the regulated negative supply is greater than that of the regulated positive supply, V-7 is not functioning properly and its

wiring, components, voltage readings and resistance readings to ground should be checked.

When the plate of V-7B is appreciably less positive than normal, the grid pin 4 of V-8, which is normally at -3.7 volts, should be more negative. If this grid of V-8 is not appreciably more negative than normal, check the components, wiring and resistance readings associated with this grid of V-8.

When the grid pin 4 of V-8 is more negative than normal the plate current in V-8 will normally decrease and balance the positive and negative regulated supplies.

When the center-tap regulator remains unbalanced even though the grid pin 4 of V-8 is more negative than normal, check V-8 and associated circuitry. The trouble may be due to a malfunction not originating in the center-tap regulator. An excessive unbalance in the current drain due to a malfunction in the main or AVC amplifier can prevent the center-tap regulator from operating properly. Under this condition, since the operating voltages are incorrect, the main and AVC amplifier can be tested only by checking their resistance readings to ground. See "MAIN AMPLIFIER" on page 18 and "AVC AMPLIFIER" on page 19 and Figure 8 for resistance readings to ground.

When the center-tap regulator is unbalanced and the magnitude of the regulated positive supply is greater than the regulated negative supply, the grid of V-7A which is normally at zero volts will be more positive. This increases the current in V-7A and decreases the current in V-7B. The plate of V-7B which is normally at +150 volts, should be more positive because of the decreased plate current. If the plate of V-7B is not appreciably more positive than normal when the regulated positive supply is greater than the regulated negative supply, V-7 is not functioning properly and its components, wiring, voltage readings and resistance readings to ground should be checked.

When the plate of V-7B is appreciably more positive than normal the grid pin 4 of V-8, which is normally at -3.7 volts, should be less negative. If this grid of V-8 is not appreciably less negative than normal, check the components, wiring and resistance readings associated with this grid of V-8.

When the grid pin 4 of V-8 is less negative than normal, the plate current of V-8 will normally increase and balance the positive and negative regulated supplies.

When the center-tap regulator remains unbalanced even though the grid pin 4 of V-8 is less negative than normal, check V-8 and associated circuitry. The trouble may be due to a malfunction not originating in the center-tap regulator. An excessive unbalance in the current drain due to a malfunction in the main or AVC amplifier can prevent the center-tap regulator from operating properly. Under this condition, since the operating voltages are incorrect, the main and AVC amplifiers can be tested only by checking their resistance readings to ground. See "MAIN AMPLIFIER" on page 18 and "AVC AMPLIFIER" on page 19 and Figure 8 for resistance readings to ground.

B. MAIN AMPLIFIER

Under normal conditions the output d-c level of the main amplifier should be 0±1 volt as measured at the sine wave output terminals when the RMS VOLTS control is set at maximum output.

The output d-c level is maintained at this value because it is compared with ground in the differential amplifier V-4. The grid of V-4B (pin 1) is connected to ground and the grid of V-4A is connected via the RC network to the output of the main amplifier V-5.

There are two likely malfunctions that might occur outside the main amplifier that would result in an incorrect output d-c level even though the main amplifier is functioning properly. When the sine wave output is excessively distorted, or the d-c path in the RC network is interrupted, the output d-c level of the main amplifier will differ from its normal value. Before checking the main amplifier it is advisable to eliminate the possibility of these two malfunctions. Excessive sine wave amplitude can be eliminated by stopping the Oscillator from functioning. Switch the frequency multiplier control to X100, set the frequency dial to 10, and connect a 1 MFD condenser from the control grid pin 4 of V-4 to ground. If the output d-c level returns to its normal value, 0±1 volt, the level determining components in the main amplifier are functioning properly and the trouble is, probably, in the AVC amplifier, which is described in "AVC AMPLIFIER" on page 19. If the output d-c level does not return to its proper value, check the possibility of an open circuit in the d-c path of the RC network. Short circuit the RC network by connecting a jumper from the output of the main amplifier V-5 (pin 6) to the input of the main amplifier V-4A (pin 4). Check the output d-c level of the main amplifier with the jumper and the 1 MFD condenser connected. If the level returns to its normal value, this indicates a malfunction in the RC network. If the output d-c level does not return to its normal value when the jumper is connected, the main amplifier is not functioning properly. Remove the jumper, but leave the 1 MFD condenser connected as before.

If the output d-c level of the main amplifier is appreciably more positive than normal, the grid of V-4A will be more positive than normal. This increases the plate current in V-4A and decreases the plate current in V-4B. The plate of V-4B, which is normally at +150 volts, should be more positive because of the decreased plate current. If the plate of V-4B is not appreciably more positive than normal, when the output d-c level of the main amplifier is excessively positive, V-4 is not functioning properly and its wiring, components, voltage readings and resistance readings to ground should be checked.

If the plate of V-4B is appreciably more positive than normal, the grid of V-2B should be less negative than normal. This should increase the plate current in V-2B. The increased plate current of V-2B should decrease the plate of V-2B which is normally at +160 volts, to a less positive value. If the grid of V-2B is not appreciably less negative, or the plate of V-2B is not appreciably less positive than normal, V-2B is not functioning properly and its wiring, components, voltage readings and resistance readings to ground should be checked.

When the plate of V-2B is appreciably less positive than normal, the grid pin 4 of V-5 should be more negative than normal. If this grid is not appreciably more negative than normal, check the wiring, components and resistance readings associated with it. When this grid is more negative than normal, the plate current in V-5 will normally decrease and should restore the output d-c level of the main amplifier to its proper voltage, if V-5 and associated circuitry are not defective.

When the output d-c level of the main amplifier is appreciably more negative than normal, the grid of V-4A will be more negative than normal. This decreases the plate current in V-4A and increases the plate current in V-4B. The plate of V-4B which is normally at +150 volts, should be less positive because of the increased plate current. If the plate of V-4B is not appreciably less positive than normal when the output d-c level of the main amplifier is excessively negative, V-4 is not functioning properly and its wiring, components, voltage readings and resistance readings to ground should be checked.

When the plate voltage of V-4B is appreciably less positive than normal, the grid of V-2B should be more negative than normal. This should decrease the plate current in V-2B. The decreased plate current of V-2B should increase the plate of V-2B, which is normally at +160 volts, to a more positive value. If the grid of V-2B is not appreciably more negative than normal or the plate is not appreciably more positive than normal, V-2B is not functioning properly, and their wiring, components, voltage readings and resistance readings to ground should be checked.

When the plate of V-2B is appreciably more positive than normal, the grid pin 4 of V-5 should be more positive than normal. If this grid is not appreciably more positive than normal, check the wiring, components and resistance readings associated with it.

When this grid is more positive than normal the plate current in V-5 will normally increase and should restore the output d-c level of the main amplifier to its proper value, if V-5 and associated circuitry are not defective.

If the Oscillator exhibits a tendency to generate spurious signals or does not function properly on the high frequency ranges, one of the high frequency by-pass condensers in the main amplifier C-6 through C-9 may be open and should be checked. This can be done by disconnecting them and measuring them directly, or more easily, by shunting a condenser of the same value across them directly without removing the condenser in the instrument. If the performance of the Oscillator changes appreciably when a condenser is by-passed, the condenser is probably defective and should be replaced.

C. AVC AMPLIFIER

Under normal conditions the output d-c level of the AVC amplifier should be 0±1 volt as measured at the cathode of V-3. Since the bridge on the input of the AVC amplifier is direct coupled to the output of the

main amplifier, it is important that the output of the main amplifier be at its correct d-c level before checking the output d-c level of the AVC amplifier. To eliminate the possibility of introducing an unwanted signal into the AVC amplifier which may upset the output d-c level, it is desirable that a 1 MFD condenser be connected from the grid pin 4 of V-4 to ground. The frequency multiplier control should be switched to X100 and the Oscillator dial should be set at 10.

If the output d-c level of the AVC amplifier is appreciably more positive than normal, the grid of V-1A will be less negative than normal. This increases the plate current in V-1A and decreases the plate current in V-1B. The plate of V-1B, which is normally at +155 volts, should be more positive because of the decreased plate current. If the plate of V-1B is not appreciably more positive than normal when the output d-c level of the AVC amplifier is excessively positive, V-1 is not functioning properly and its wiring, components, voltage readings and resistance readings to ground should be checked.

If the plate of V-1B is appreciably more positive than normal, the grid of V-2A should be less negative than normal. This should increase the plate current in V-2A and decrease the plate voltage, which is normally at +120 volts, to a less positive value. If the grid of V-2A is not appreciably less negative or the plate of V-2A is not appreciably less positive than normal, V-2A is not functioning properly and its wiring, components, voltage readings and resistance readings to ground should be checked.

When the plate of V-2A is appreciably less positive than normal, the grid of V-3 should be more negative than normal. If the grid of V-3 is not appreciably more negative than normal, check the wiring, components and resistance readings associated with the grid of V-3. When the grid of V-3 is more negative than normal, the plate current will decrease and should restore the output d-c level of the AVC amplifier to its proper voltage.

When the output d-c level of the AVC amplifier is appreciably more negative than normal, the grid of V-1A will be more negative than normal. This decreases the plate current in V-1A and increases the plate current in V-1B. The plate of V-1B, which is normally +155 volts, should be less positive because of the increased plate current. If the plate of V-1B is not appreciably less positive than normal when the output d-c level of the AVC amplifier is excessively negative, V-1 is not functioning properly and its wiring, components, voltage readings and resistance readings to ground should be checked.

When the plate of V-1B is appreciably less positive than normal, the grid of V-2A should be more negative than normal. This should decrease the plate current of V-2A and increase the plate voltage, which is normally at +120 volts, to a more positive value. If the grid of V-2A is not appreciably more negative than normal or the plate is not appreciably more positive than normal, V-2A is not functioning properly, and its wiring, components, voltage readings and resistance readings to ground should be checked.

When the plate of V-2A is appreciably more positive than normal, the grid of V-3 should be more positive than normal. If the grid of V-3 is not appreciably more positive than normal, check the wiring, components and resistance readings associated with the grid of V-3.

When the grid voltage of V-3 is more positive than normal, the plate current will increase and should restore the output d-c level of the main amplifier to its proper voltage.

If the Oscillator exhibits a tendency to generate spurious signals or does not function properly on the high frequency ranges, one of the high frequency by-pass condensers C-1 to C-5 in the AVC amplifier may be open circuited and should be checked. This can be done by disconnecting them and measuring them directly, or more easily by shunting a condenser of the same value across them directly without removing the condenser in the Oscillator. If the performance of the Oscillator changes appreciably when a condenser is by-passed, the condenser is probably defective and should be replaced.

D. FREQUENCY CONTROL CIRCUITS

If the Oscillator is operating erratically on some bands or the frequency calibration deviates from its indicated value, the frequency multiplier band switch, the tuning potentiometer, or the frequency determining condensers of the network may be defective. Adjust C-15A to correct calibration on band 5. If the contacts on all the switches are excessively dirty, direct a stream of compressed air at them and then check each contact with an ohmeter. If necessary, clean the contacts with fine emery paper.

As shown in the diagram of Figure 3, the RC network consists basically of two resistors and two condensers. The effective resistances R_a and R_b are varied by the tuning dial, and the condensers C_a and C_b are varied by the frequency multiplier switch.

The values of the frequency control condensers C-10 through C-15 are shown on the Schematic, Figure 7, and can be checked with a suitable impedance bridge without disconnecting any leads or components. All of the condensers can be checked on band 1 position of the MULTIPLY DIAL BY switch, excepting C-10 and C-11, which should be checked on band 3.

E. SQUARE WAVE GENERATOR

When the triode multivibrator, tube V-9, is operating properly, V-9A is conducting and V-9B is nonconducting during the positive excursion of the sine wave signal. During the negative excursion of the sine wave signal V-9B becomes conducting and V-9A becomes nondonducting. The plate of V-9B should alternate between +16 volts and +142 volts. If the plate of V-9B does not alternate between these two voltages, V-9 is not functioning properly and the wiring, components, voltage readings and resistance readings to ground should be checked. The symmetry or d-c level can be adjusted by changing the value of R-55 or R-51 respectively.

SECTION V - MAINTENANCE

F. SIGNAL TRACING ANALYSIS

The following procedure may facilitate the localizing of a malfunction, if the d-c voltages and resistance checks show no appreciable discrepancy.

Set the dial at 10, MULTIPLY DIAL BY switch on X100, RMS VOLTS full clockwise, POWER switch ON. Connect a 4 MFD or larger non-electrolytic condenser to pin 4 of V-4. Connect the other end of this condenser through a resistor of approximately 100 ohms to ground (chassis). Then connect a resistor of approximately 22,000 ohms from the junction of the 100 ohms and the condenser to an external oscillator, with the ground terminal of the oscillator connected to chassis. Set the output of the external oscillator to approximately 7.5 volts rms at 1 kc.

Compare the observed 1 kc signals with those listed in the Signal Tracing Table, Figure 6. Readings which differ by a factor of 2 from those listed may not necessarily indicate any serious trouble. The checks should be made in the order listed in the Signal Tracing Table, Figure 6. Use an oscilloscope (with the external synchronizing input connected to the external oscillator for phase measurements).

SECTION VI - SERVICE AND WARRANTY

KROHN-HITE Instruments are designed and manufactured in accordance with sound engineering practices, and should give long trouble-free service under normal operating conditions. If your Oscillator fails to provide satisfactory service and you are unable to locate the source of trouble, write to our Service Department giving all the information available concerning the failure.

Do not return the instrument without our written authorization for in most cases we will be able to supply you with the information necessary to repair the Oscillator and thus avoid the transportation problems and costs. When it becomes necessary to return the instrument to our factory, kindly pack it carefully and ship it to us via express, prepaid.

KROHN-HITE Instruments are conservatively designed to provide continuous reliable service under normal laboratory conditions. The material and workmanship in every instrument is guaranteed for one year from the date of purchase. Any instrument developing defects during this period will be repaired or defective parts will be replaced without charge when the failure is the result of defective material or workmanship. Our warranty does not apply to vacuum tubes.

KROHN-HITE reserves the right to make design changes at any time without incurring any obligation to incorporate these changes in instruments previously purchased.

CHECK POINT	1 KC AMPLITUDE IN VOLTS	PHASE FROM EXTERNAL OSCILLATOR	WAVE FORM	LOCATIONS OF TROUBLE IF INCORRECT
Pin 4, V-4	0.038 rms	0°	sine wave	V-4 or freq. control
Pin 2, V-4	0.76 rms	0°	sine wave	V-4 tube & parts
Pin 5, V-2	18 rms	180°	sine wave	V-2B tube & parts
Pin 6, V-5	10 rms	180°	sine wave	V-5 tube & parts
Sine Wave * Output	10 rms	180°	sine wave	P-2
Pin 5, V-9	126 p to p	180°	square wave	V-9 tube & parts
Pin 1, V-1	0.56 rms	180°	sine wave	R2, R3, C2, R16, R17
Pin 4, V-1	0.52 rms	180°	sine wave	I1, P1, R7
Pin 5, V-1	1.8 rms	180°	sine wave	V-1 tube & parts
Pin 2, V-2	4.4 rms	0°	sine wave	V-2 tube & parts
Pin 3, V-3	2.2 rms	0°	sine wave	V-3 tube & parts
Pin 4, V-3	16.8 p to p	180°	sine wave with positive swing clipped	V-3, R20, R21, R3
Pin 5, V-3	7.0 p to p	180°	sine wave with positive swing clipped	V-3, R18, R19, R7
Center Arm of S-3F	2.5 rms	90° lag	sine wave	Freq. control circuit
Pin 2, V-7	0.085‡ rms	0°	spikes and ripple	Power Supply

FIGURE 6 - SIGNAL TRACING TABLE

* After checking the signal voltage on this sine wave output, reset the output of the external oscillator to get a reading of 10 volts rms on this sine wave output. Then check the next steps (pin 5 of V-9 etc).

‡ A smaller signal does not indicate trouble.

AVC AMPLIFIER

MAIN AMPLIFIER

POWER SUPPLY

TUNING POTS

SQUARE WAVE GENERATOR

FREQUENCY CONTROL
S2 - BAND SWITCH SHOWN IN MAX. C.C.W. POSITION

NOTE: BANDSWITCH MULTIPLIERS SHOULD READ .01 TO 100

NOTE
T1 HIGH VOLTAGE SECONDARY WINDING DESIGNED TO DEVELOP 390 V.D.C. ACROSS C18, WITH A 75 MA. LOAD AND 115 VOLT LINE.

TUBE LAYOUT
BOTTOM VIEW

FRONT

1) ALL RESISTORS ½W 5% UNLESS OTHERWISE SPECIFIED
2) ALL CONDENSERS MMF 20% 500VDC UNLESS OTHERWISE SPECIFIED
3) ALL COMPONENTS MARKED TRIM ARE FACTORY ADJUSTMENTS

REVISED FOR SER. NO. 431

MODEL 400-A

SCALE NONE	FIGURE 7	DRAWN BY AHW
DATE 8/5/57		REVISED 3-15-63

SCHEMATIC
ULTRA-LOW FREQUENCY OSCILLATOR

KROHN-HITE CORPORATION
CAMBRIDGE MASS. USA

DRAWING NUMBER 400-A-2

PUB. DEPT. DRAWING NO. 400A-1 REVISED BY PUB. DEPT.

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